SOARD

Research Portfolio

AFOSR Spring Review

March 2013

James Fillerup, PE, Director

Southern Office of Aerospace Research and Development

Air Force Office of Scientific Research

Integrity ★ Service ★ Excellence

Report Documentation Page

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SOARD - Smallest of Int'l Offices

Two Project Officers cover a broad range of scientific disciplines

(rule of thumb: if a topic of the AFOSR BAA - check it out)

FY12: 42 projects / 33 Institutions

- **Primary focus - Fillerup**
  - **Space Sciences**
  - **Material Sciences**
  - **Structural Mech / Aerodyn**

- **Primary focus - Pokines**
  - **Nanomaterials**
  - **Bionano**
  - **Aero morphing systems**

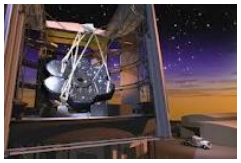
SOARD relies on AFOSR POs expertise.

Briefing Contents

- **Space Science Portfolio**
  - Solar, Ionosphere, Magnetosphere (Kent Miller (AFOSR), RV)
- **Molecular Physics**
  - Isotope Decay Project (Tom Hussey, John Luginsland (AFOSR), Maj Robert Lee, (USAFA))
- **Material Science**
  - Ferroelectric Nanoparticles (Charles Lee (AFOSR), Dean Evans (RX))
  - Extremophiles: Synthesis of Se nanoparticles (Hugh DeLong (AFOSR))
- **Structural Mechanics**
  - Filament Wound Structures (Matt Triplett, (Army ARDEC), Dave Stargel (AFOSR)
- **Aerodynamics**
  - Stability of Coaxial Jets (Ivett Leyva (RQ))

Space is Big in So. Am.
Astronomical Observatories - Chile



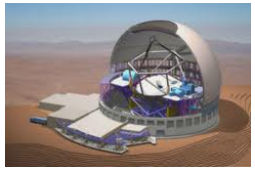


Las Campanas Observatory
(Carnegie)



Gemini Observatory
(Int'l partners - twin telescope in Hawaii)





Cerro Tololo Observatory
(NSF)

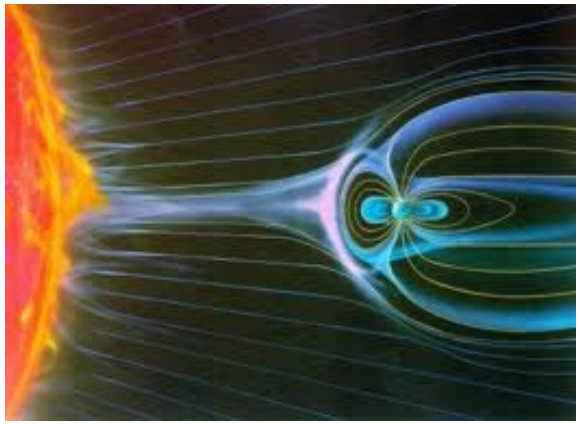


Alma Radio Observatory
(Several Int'l partners)

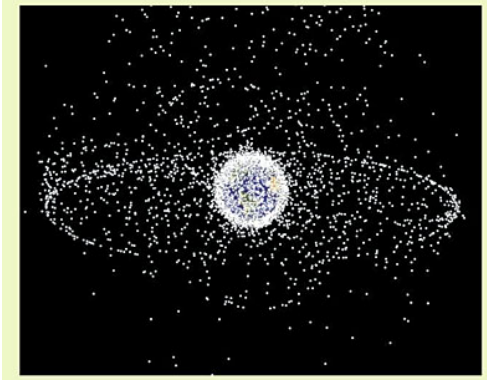
Chilean researchers get 10% of time - no charge
Created strong Univ. Astrophysics Departments

AF interest in Space Science

- **Forecasting the geospace environment of Earth, for <u>Space Situational Awareness</u>**
  - **Solar Physics**
  - **Magnetospheric Physics**
  - **Ionospheric and Thermospheric Physics**



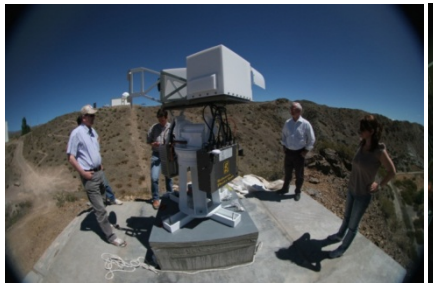
- **Necessary for:**
  - **Satellite drag predictions**
  - **Radiation belt perturbations**
  - **Communications/navigation/surveillance**

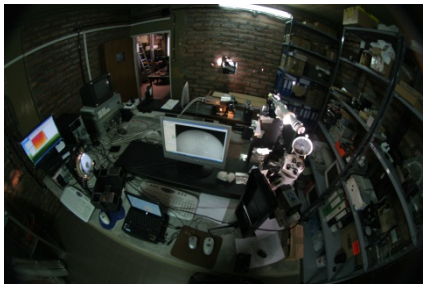


So. Am. partnerships provide access to southern hemisphere skies

Solar Physics Research

Leoncito Astronomical Complex – Argentina





Solar Observatory Facility

Facility owned by Brazil - Operated by CASLEO

The Search For New Approach To Detect Solar CME Precursors At Sub-THz And Mid-IR Frequencies

CASLEO Observatory Complex

Collaborators:

- AFOSR / RV, US
- University Mackenzie, Brazil (Lead PI: Pierre Kaufmann)
- UNICAMP, Brazil
- USP, Brazil
- CASLEO, Argentina

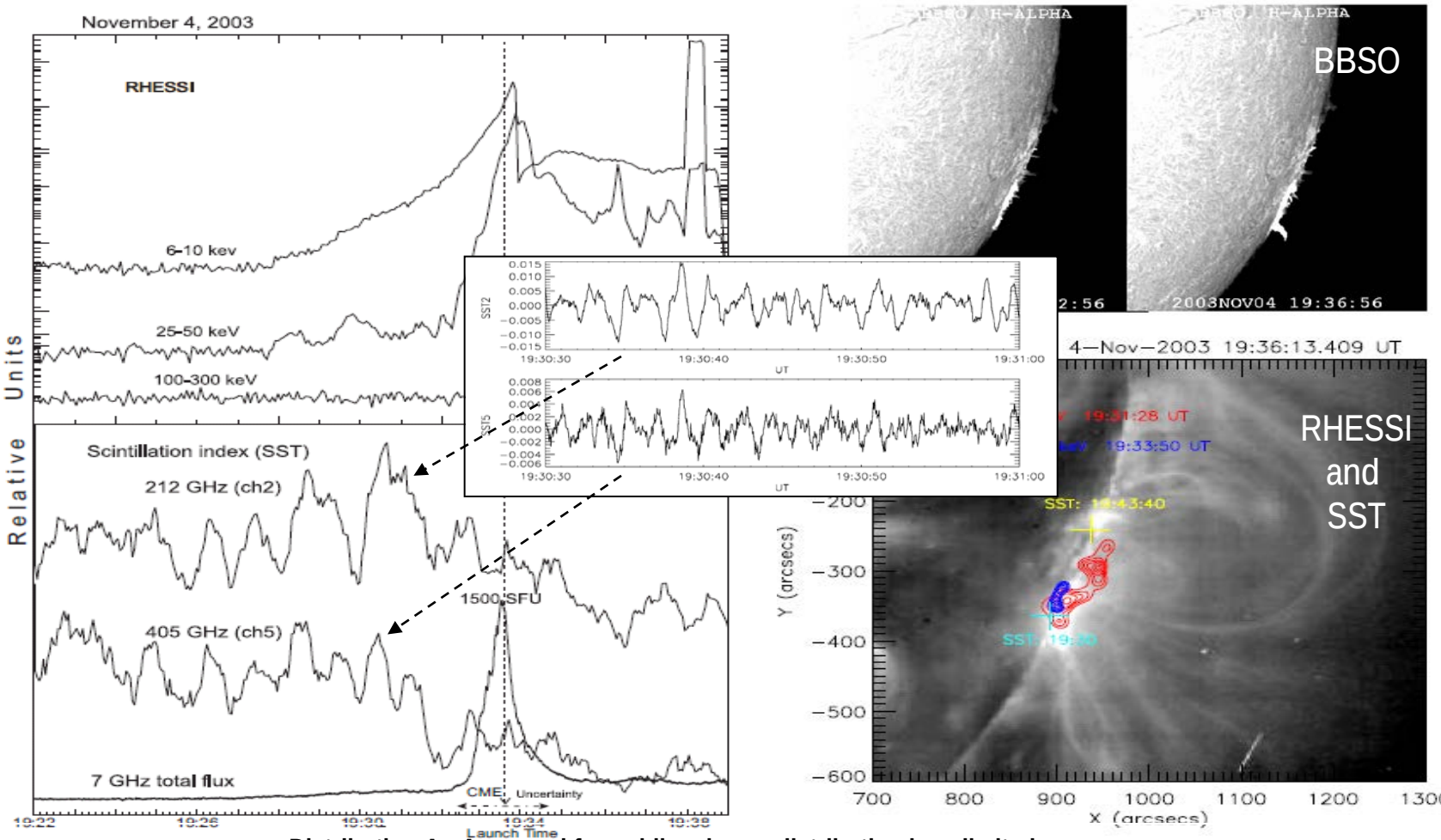
Supporting agencies

- FAPESP, CNPq, Brazil
- CONICET, Argentina
- AFOSR, US

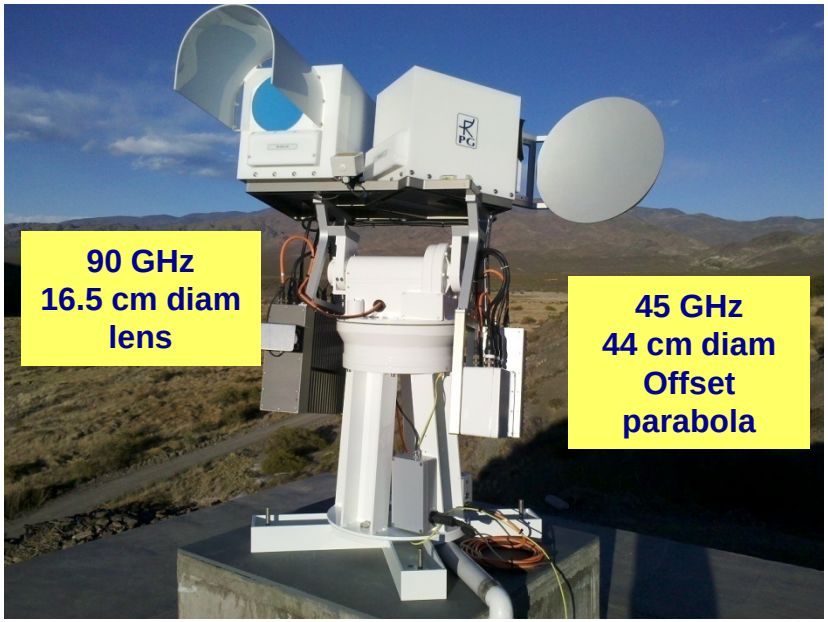
Solar Physics

Submm-w 2 sec pulsations maximize with CME launched nearly 10 min before large flare onset!

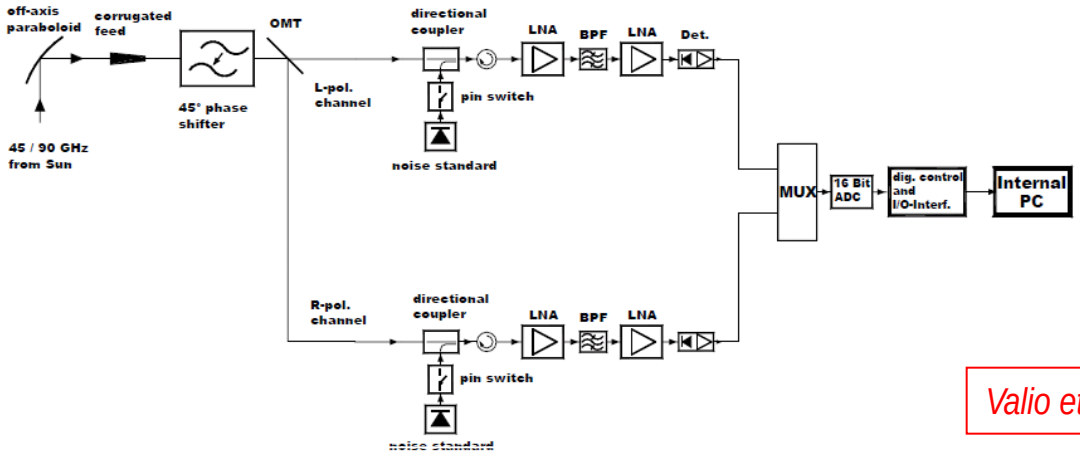
Kaufmann et al., Solar Phys. 2012



Solar Circular Mm-w Polarization Patrollers
(Operations at CASLEO started November 2011)

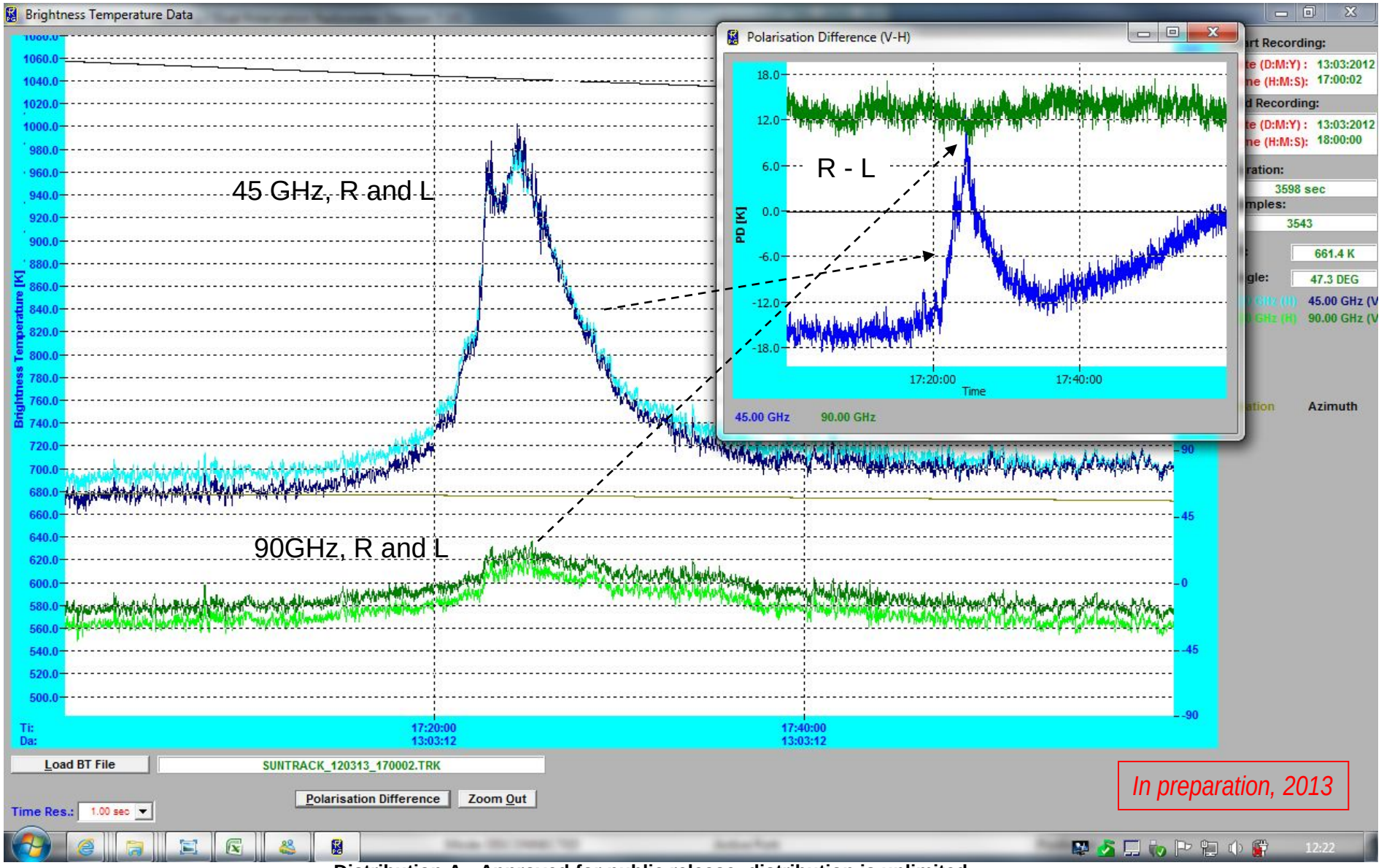


Covers the spectral frequency gab from 20 to 200 GHz



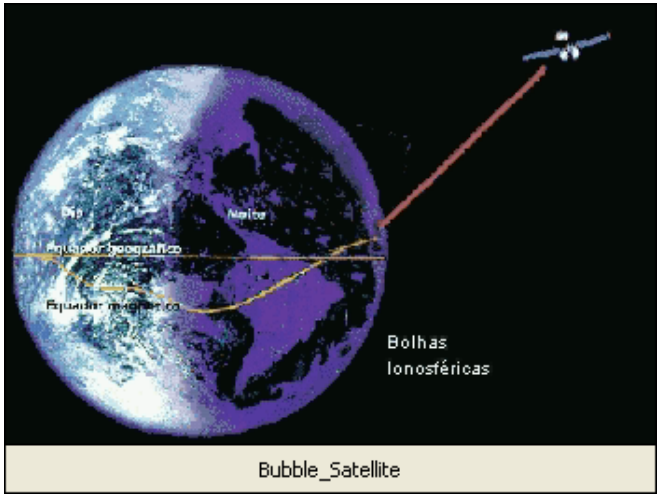
Valio et al., Solar Phys. 2013

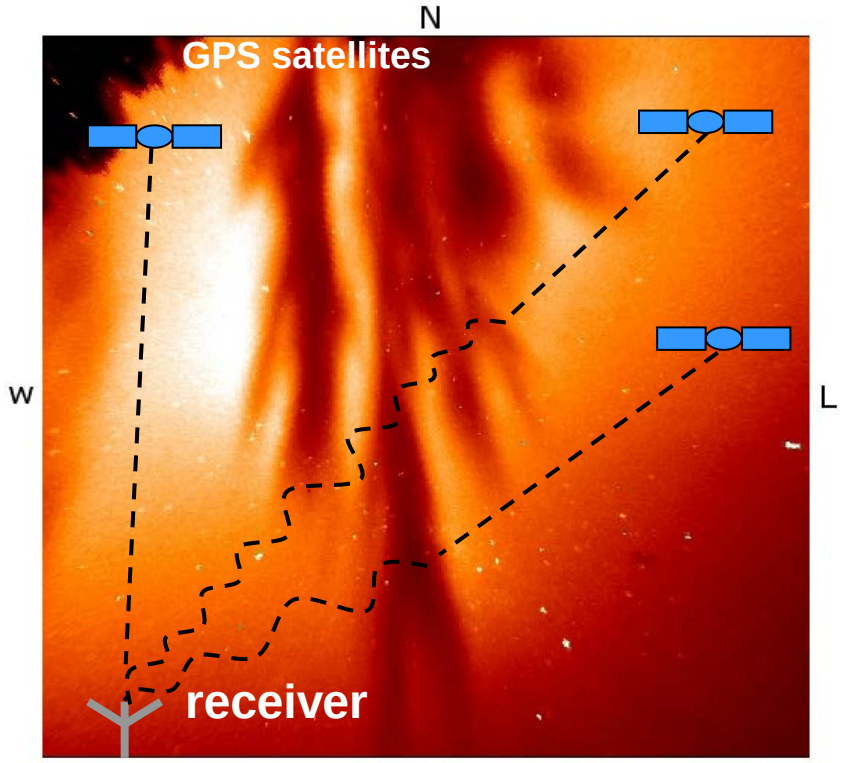
13 March 2012 solar burst – also observed at 200 GHz, 30 THz, Hα at El Leoncito; by AFRL RST microwaves and by SDO – currently under joint investigation



In preparation, 2013

Ionosphere Research with Brazil

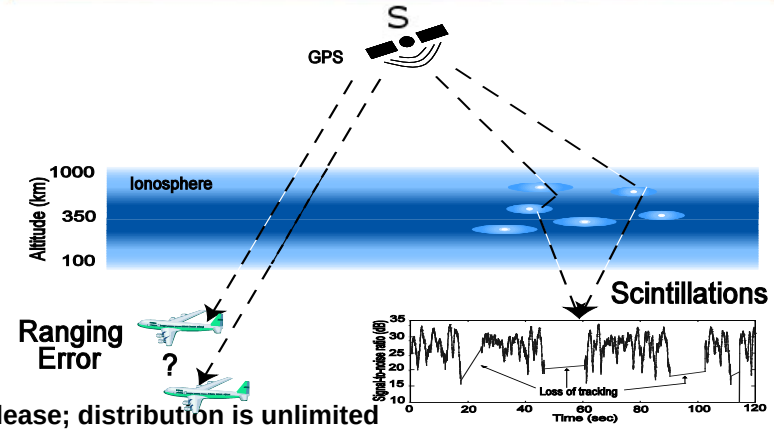




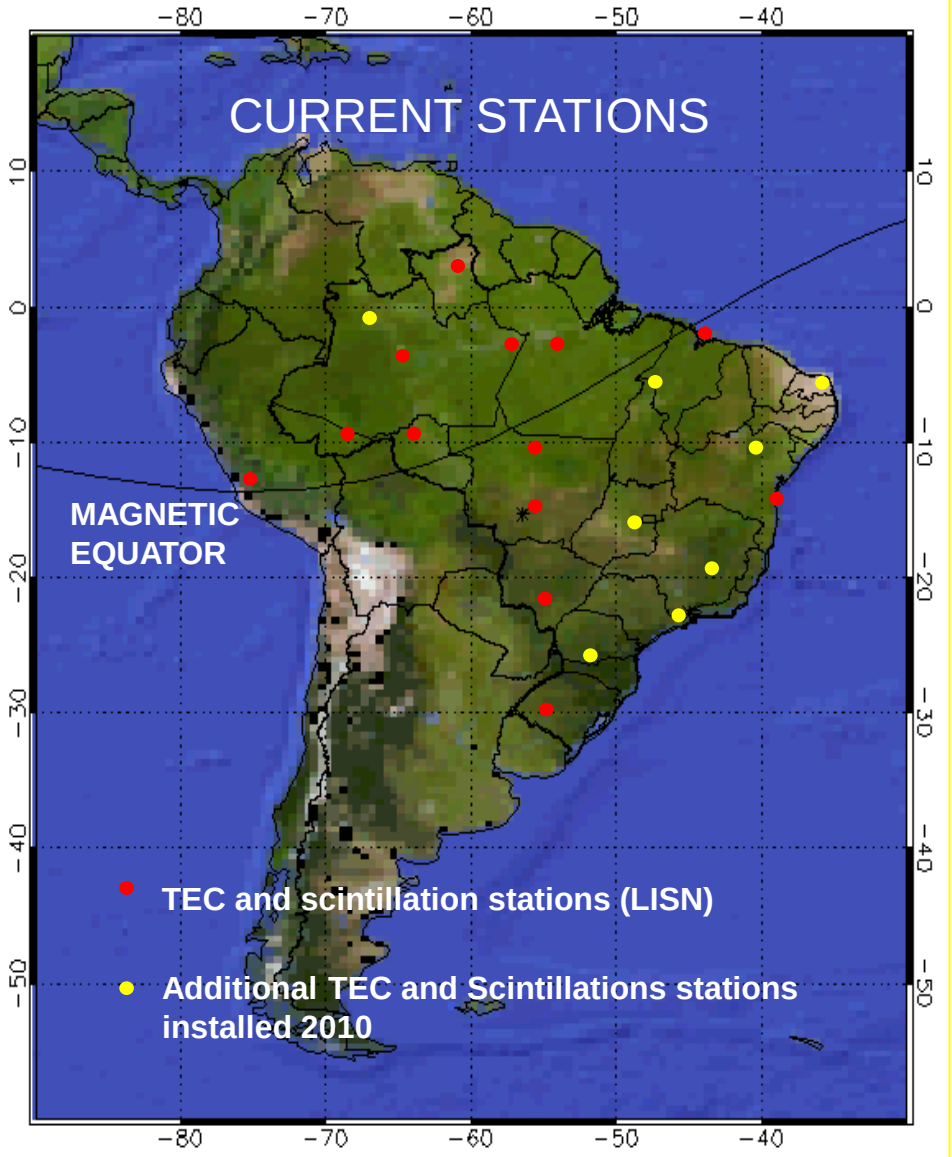
The Problem:

Ionospheric bubbles are rarefied plasma regions. Ionospheric irregularities inside the bubbles have scale size varying from cm to km.

The amplitude fading (scintillations) if deep enough and long enough, can potentially cause tracking loss.



Data Collection Stations - Brazil



GPS scintillation stations in Brazil

LISN / NSF

Santa Maria-RS,
Porto Velho-RO
Rio Branco-AC
Parintins-AM
Tefé-AM
Boa Vista-RR
Dourados-MS
Santarém-PA
Alta Floresta-MT
Ilhéus-BA
Cuiabá-MT
São Luís

Additiona Stations (2010):

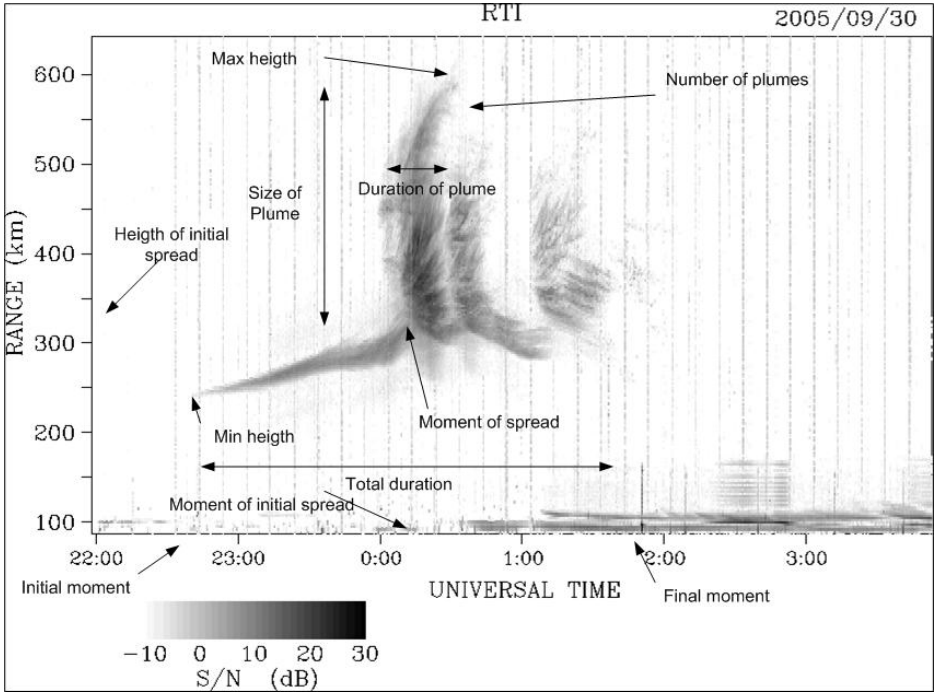
Belo Horizonte MG
Brasília
Natal RN
Pato Branco PR
Imperatriz-MA
Petrolina-PE
São José dos Campos SP
São Gabriel da Cachoeira AM

Also LISN station at Alcon, Peru

Project: "Ionospheric Irregularities Predictions and Plumes Characterization for Satellite Data Validation"

PI: Eurico de Paula, National Institution for Space Research (INPE)

São Luis Station, Brazil



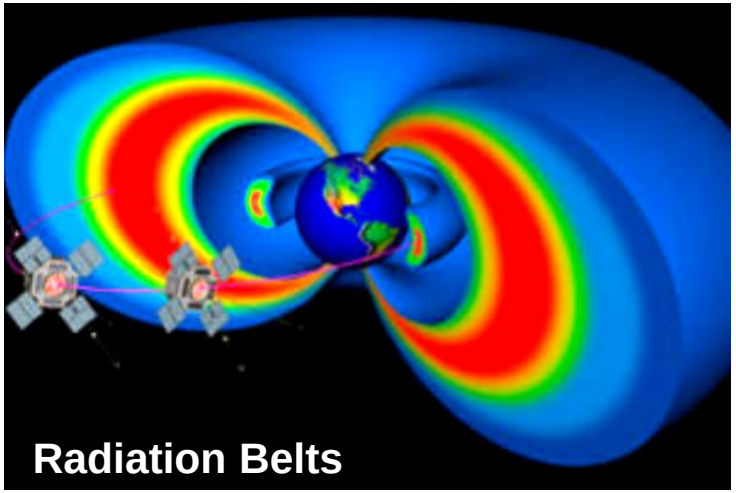
Example: São Luis VHF incoherent scatter radar plumes analysis

GPS antennas at São Luis during the AFRL/INPE campaign (installation on February 2008)

Cooperation in Atmospheric, Ionospheric and Magnetospheric Research MOU.

- MOU signed in June 2001. SAF/IA is in process of negotiating a new MOU.

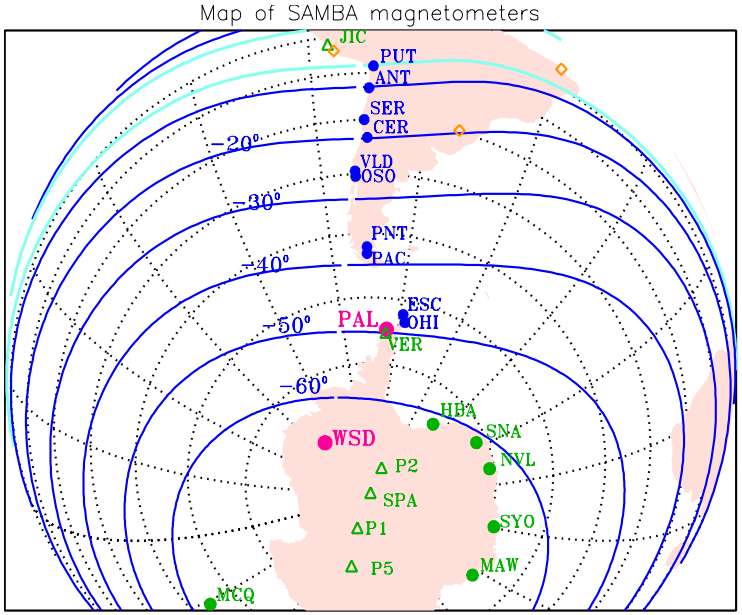
Magnetosphere Research



Objective: Study of geomagnetic phenomena (i.e., magnetic storms) and processes that affect particle fluxes in the radiation belts

Collaborators:

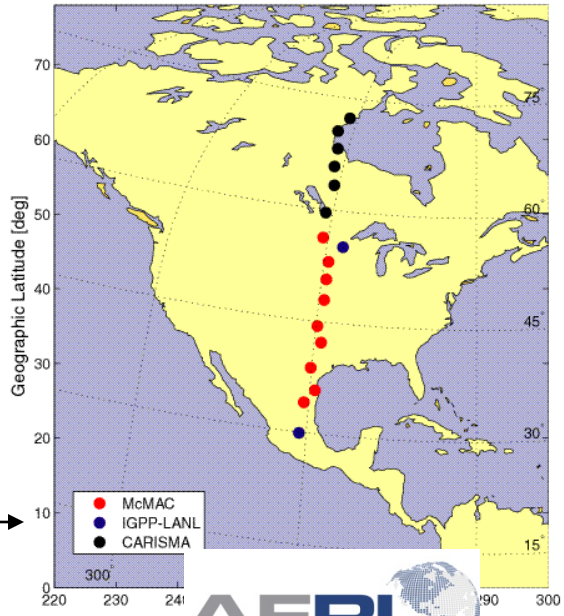
- **US:**, NASA, RV, Boston College
- **Chile:** U of Santiago, (Lead PI: Stepanova), U of Chile, U of Concepcion



Magnetometer Monitoring Stations

SAMBA Stations (in Chile)

McMAC
IGPP-LANL
CARISMA



USAFA
SSA Tracking Telescope in Chile

Mamalluca Observatory
Future site of USAFA tracking telescope

Proposed FTN Station and 50 cm telescope

USAFA Falcon Telescope Network (FTN) For SSA

- Space Situational Awareness (SSA) - To detect, track, identify, image, predict future positions of space objects
- A network of remote telescopes with one located in Chile providing access to southern hemisphere

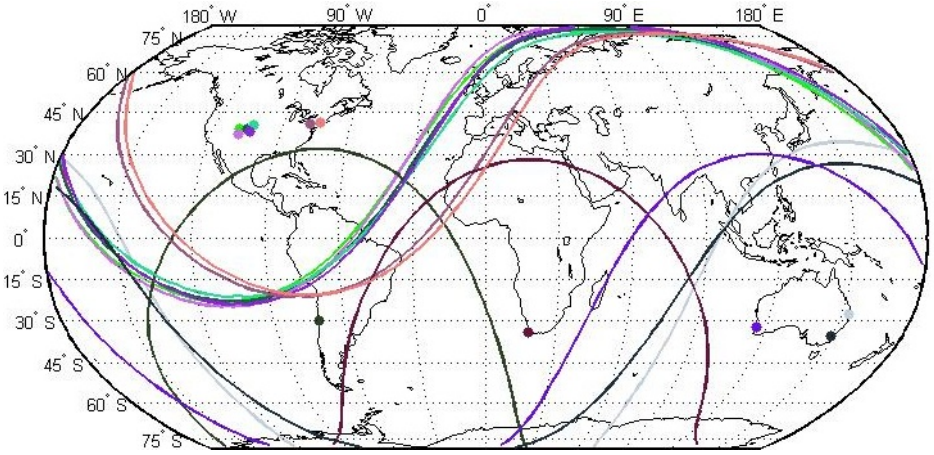
Collaborators

- USAF Academy
- AFOSR / RV
- Universidad of La Serena
- Mamalluca Observatory

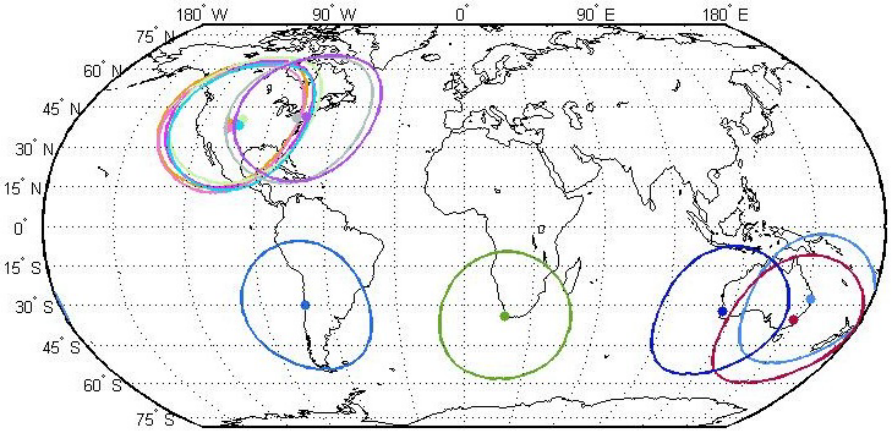
FTN: Global Coverage

Partners

- **U.S**
  - Colorado Mesa University (Grand Junction)
  - Fort Lewis College (Durango)
  - Northeastern Junior College (Sterling)
  - Otero Junior College (La Junta)
  - Penn State University (State College)
- **Chile**
  - Universidad de La Serena (La Serena) & Observatorio Mamalluca (Vicuña)
- **Australia**
  - University of Queensland (Brisbane)
  - Curtin University (Perth)
  - University of New South Wales & EOS (Canberra)
- **Potential:** South Africa, Kauai Community College, International Space University



Global Coverage (GEO)



Global Coverage, (LEO, 1000 km)

Created by C1C Lance Wilhelm and C1C Brandon Mueller

Molecular Physics
Periodic Nuclear Decay Rates

The Mystery of Periodic Nuclear Decay Rates

- **Familiar exponential decay law:**

$$\dot{N}(t) \equiv \frac{dN}{dt} = -\lambda N_0 e^{-\lambda t}$$

- **Periodic Variations Reported in 25 Long-term Nuclear Decay Experiments**
  - Select β & E.C. Decay Affected
  - Wide variety of detectors types
  - Few experiments run for many years; independent confirmation difficult

Raises the possibility that either the detectors or the decays in question are being affected in some fashion by an external influence such as seasonal variations or solar radiation.

Regardless of causality, understanding nature of periodicities offers crucial insight into long-term detector operations supporting scientific, national defense, and industrial applications.

Isotope	Effect Observed
^{3}H	Periodicity: 1 yr^{-1}
^{3}H	Periodicity: 1/d, 12.1 yr^{-1}, 1 yr^{-1}
^{3}H	Periodicity: ~12.5 yr^{-1}
^{3}H	Periodicity: ~2 yr^{-1}
^{22}Na/^{44}Ti[a]	Periodicity: 1 yr^{-1}
^{36}Cl	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}
^{36}Cl	Periodicity: 1 yr^{-1}
^{54}Mn	Periodicity: 1 yr^{-1}
^{56}Mn	Periodicity: 1 yr^{-1}
^{60}Co	Periodicity: 1 yr^{-1}
^{60}Co	Periodicity: 1/d, 12.1 yr^{-1}
^{85}Kr	Periodicity: 1 yr^{-1}
^{90}Sr/^{90}Y	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}
^{108m}Ag	Periodicity: 1 yr^{-1}
^{133}Ba	Periodicity: 1 yr^{-1}
^{137}Cs	Periodicity: 1 yr^{-1}
^{152}Eu	Periodicity: 1 yr^{-1}
^{152}Eu	Periodicity: 1 yr^{-1}
^{154}Eu	Periodicity: 1 yr^{-1}
^{222}Rn[c]	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}
^{226}Ra[c]	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}
^{239}Pu	Periodicity: 1/d, 13.5 yr^{-1}, 1 yr^{-1}

CCHEN Decay Experiment:
Present Status

Detector Network of 4 Sites

- Chilean Commission of Nuclear Energy (CCHEN)
- USAFA
- Purdue University
- Brigham Young University

- **Mimic IMS Measurements but at Higher Data Rates & longer Integration Times**

- **Variety of Detectors, Sources**
  - Empty Detectors as Control
  - Monitor Environ. Variables
  - Custom, Full Lead Shielding

- **CCHEN detectors set up & calibrated in Sept 2012**
  - Data looks good, but too soon to evaluate significance
  - Expect 2 yr runtime, first results in 9 months

View of Test Chambers (top), Gieger Mueller and NaI Detectors with ^{54}Mn, ^{32}Si, ^{36}Cl, ^{90}Sr, and empty NaI detector in separate chamber

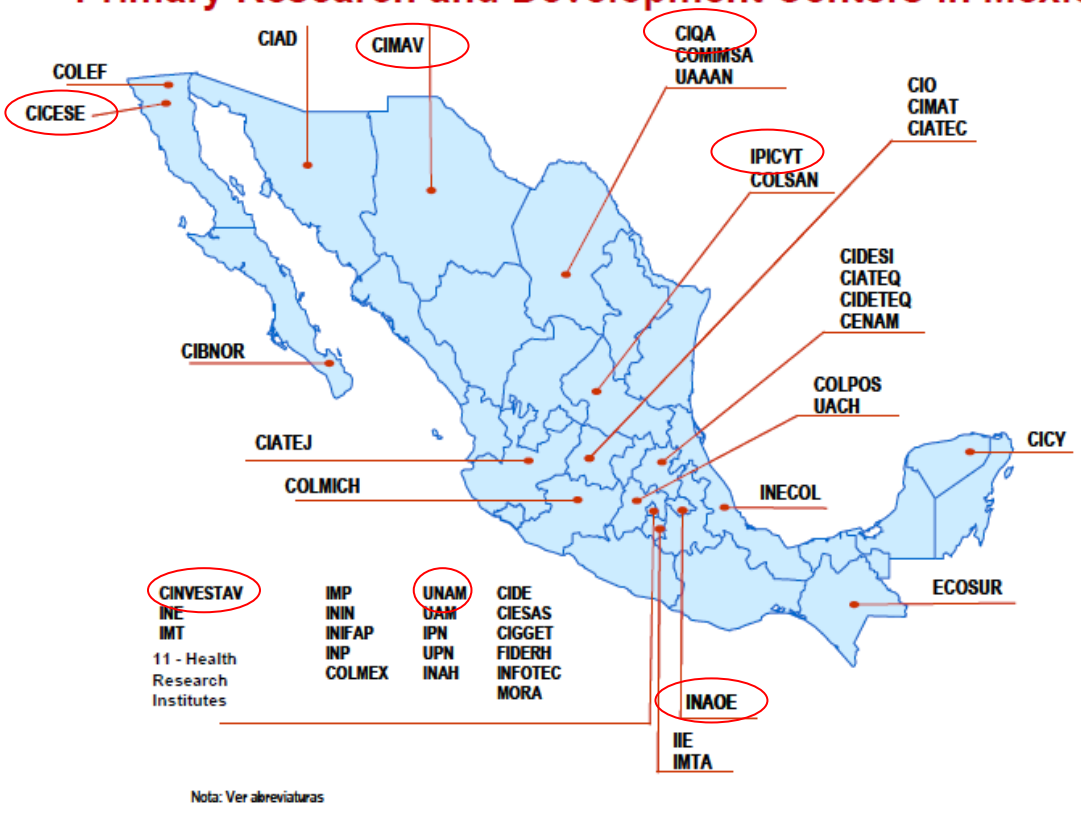
Material Science
and the Mexican Initiative

Exact & Natural Sciences

CIAD	Food products and processes, social and economic development related to food products and processes
CIBNOR	Sustainable management of natural resources
CICESE	Biological sciences, physics, information technology, marine and geological
CICY	Biological vegetation, natural resources and materials science
CIMAT	Mathematics, probabilities, statistics and computational sciences
CIMAV	Nanotechnology, materials, environment and energy
CIO	Optics
INECOL	Ecology, biodiversity and natural resources management
INAOE	Astrophysics, optics, electronics and computational sciences
IPICYT	Molecular biology, biotechnology, geosciences, advanced materials, nanotechnology, environmental sciences and applied mathematics
CIQA	Polymer synthesis, polymerization processes, plastics transformation, advanced materials, and agricultural plastics

CONACYT Research Centers

Primary Research and Development Centers in Mexico.



National Labs work with universities, but, only receive graduate students.
Major funding support by CONACYT

AFOSR – CONACYT Joint Projects

AFOSR – CIMAV – CONACYT "U.S. / México – Basic Research Initiative"

BASIC RESEARCH PROJECTS:

Project 1: "Modeling, Development and Characterization of Alternate Electrodes for Flexible Electronics Applications."

The University of Texas at Dallas:	CIMAV - Unidad Monterrey
• Dr. Bruce Gnade, Ph.D.	• Dr. Francisco Servando Aguirre-Tostado

Project 2: "Multi-Phase, Multifunctional Ceramic Coatings."

The University of California at Santa Barbara:	CINVESTAV – Unidad Querétaro:
• Dr. Carlos Levi, Ph.D.	• Dr. Gerardo Trápaga-Martínez

Project 3: "Hybrid Solid-State Photovoltaic Materials and Devices."

The University of Akron:	CIQA – Saltillo:
• Dr. Matthew Espe, Ph.D.	• Dr. Ronald F. Ziolo

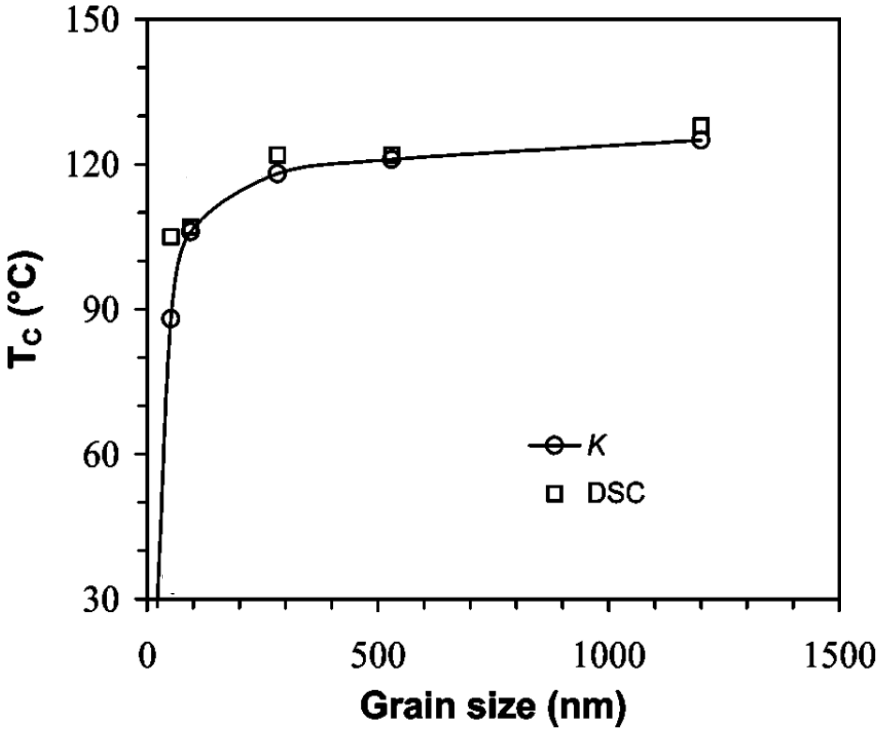
Project 4: "Laser-induced patterning of transparent ceramics and metallic films for photonic and sensing applications"

The University of California at Riverside:	CICESE – Ensenada:
• Dr. Guillermo Aguilar, Ph.D.	• Dr. Santiago Camacho-López

Final Program Review tentatively scheduled Aug - Sept 2013 in Mexico

Success story: Development of Ferroelectric Nanoparticles

Collaborators: AFRL/RXPJ, AFOSR
CIQA, Mexico



Critical temperatures of $BaTiO_3$ ceramics as a function of grain size.

Barium titanate, $BaTiO_3$, is a white powder and transparent as larger crystals. It is a ferroelectric ceramic material, with a photorefractive effect and piezoelectric properties.

- **General belief by researchers -** Typical $BaTiO_3$ loses its ferroelectricity at sizes smaller than 30-50 nm
- Size restrictions limited number of potential applications

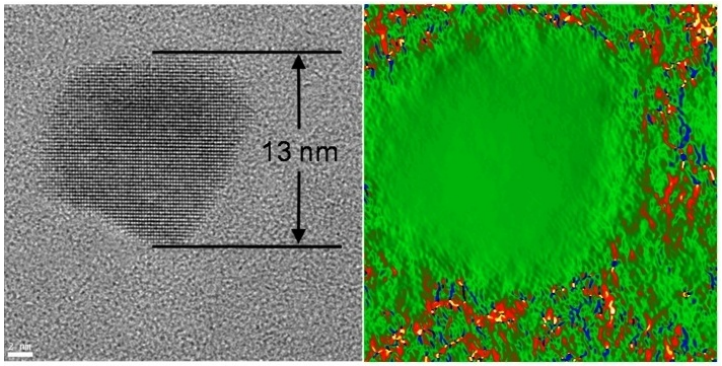
Mechanically Induced Surface Stress

Particle sizes limited to:

- **~1 µm with simple solvents**
- **9 nm with surfactant**

Bottom up – synthesizes particles from atoms and molecules
Top down –particles are reduced to nanometer size by grinding

HRTEM image Strain Map



- AFRL/RXPJ developed the world's smallest ferroelectric nanoparticle, as small as 9 nm.
- Surface stress believed key to this achievement
- Through collaboration with CIQA, a strain map was made on RXPJ's nanoparticles, proving the hypothesis that surface stress was present.

Examples of Systems with Disparate Nanoparticle Roles

- Photorefractive beam coupling: electric torque
- Liquid crystal display: DC bias
- Metatronics (Metananocircuits)
- Massive Dipole Field Effects

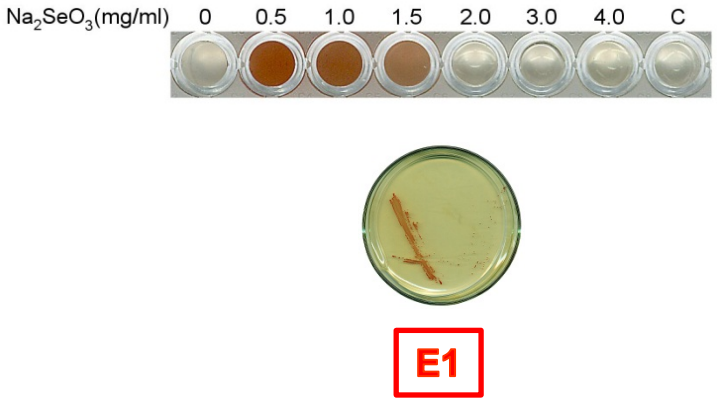
Results with 9 nm-harvested stressed ferroelectric nanoparticles

Extremophile Research

- **Collaborators: AFOSR & BioScience Foundation, Chile.**
  - **Studies started with isolation of novel heat resistant micro-organism from laboratory drying ovens: E1 and E2. (2007)**
  - **One unexpected result**: Biosynthesis of Selenium (Se) nanoparticles by E1

Identification of microorganisms

Se NANOPARTICLES BIOSYNTHESIS

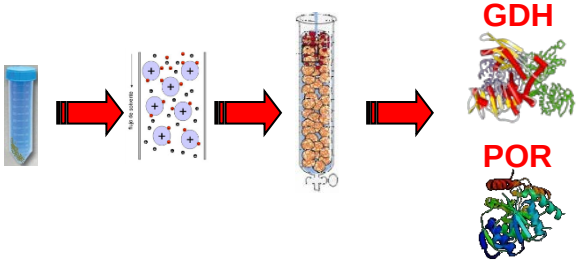


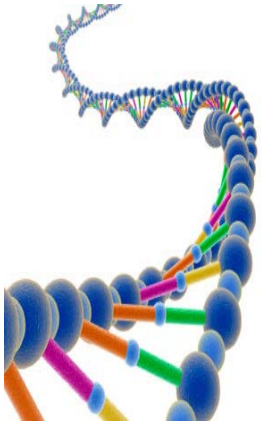
Extremophile - Accomplishments
Bioscience Foundation, Chile

Project Accomplishment

- Isolation of novel heat resistant microorganism: E1 and E2.
- Desiccation resistance for the microorganisms
- Isolation and characterization of enzymes: GDH and PDH or POR.
- Lipids Profiles and analysis. Studies of DNA repair mechanisms.
- Contribution of the antioxidant enzymes to the resistance to extreme and fluctuating UV radiation.
- Cloning and expression into *Escherichia coli* of genes

Characterization of enzymes
GDH and POR



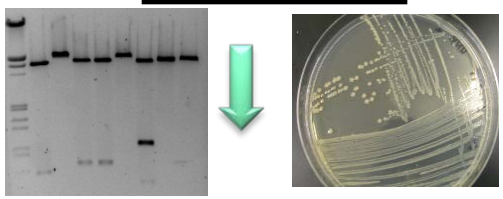


E1 Genome analysis

Catalase (CAT)

Superoxide dismutase (SOD)

Specific Primers design



Expression of genes in *E.coli*

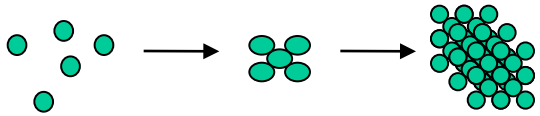
Extremophile – Future Goals
Bioscience Foundation, Chile

Research Goals to be acomplished

- To study the role of enzymes in the biosynthesis of Se nanoparticles.
- To study the effect of temperature, pH and salt concentrations in Se nanoparticle size and shape.
- To demonstrate that this is an enzyme-mediated process.

Influence of enzymes on selenium nanoparticles synthesis

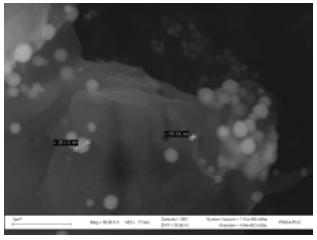
Nanocrystals biosynthesis

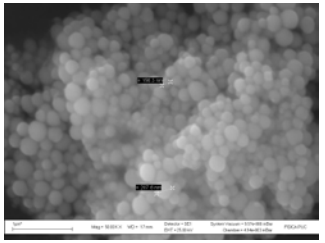


1.Local supersaturation
2.Nucleation
3.Growth

E1

Se Nanoparticles





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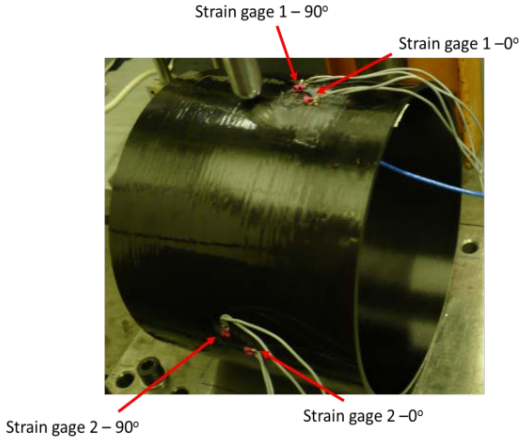
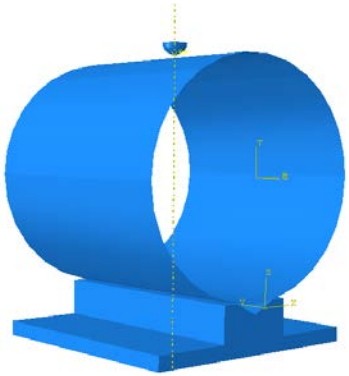
Complex phenomenon, not well studied

Structural Mechanics
Filament Wound Structures

- **Project:** Damage and Progressive Failure of Filament Wound Structures
  - Collaborators, Army ARDEC, AFOSR, and ta, Univ of Sao Paulo
- **Objective:** Investigate new mathematical formulation for damage models used in aviation filament wound structures
    - High precision, low computational cost
- **Necessary for:** structural integrity, health monitoring, and service life assessment



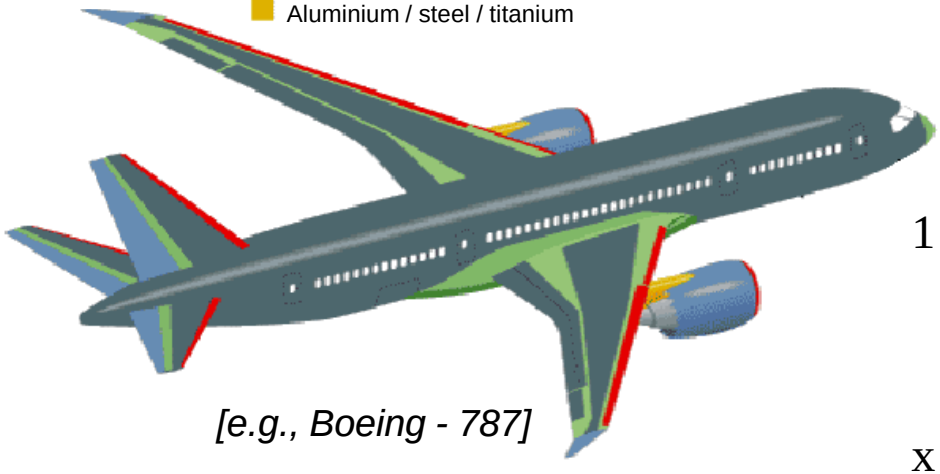


Structural Mechanics
Filament Wound Structures

Motivation

High Specific Properties

Glass fiber
Aluminium
Carbon composite laminates
Carbon sandwich composites
Aluminium / steel / titanium



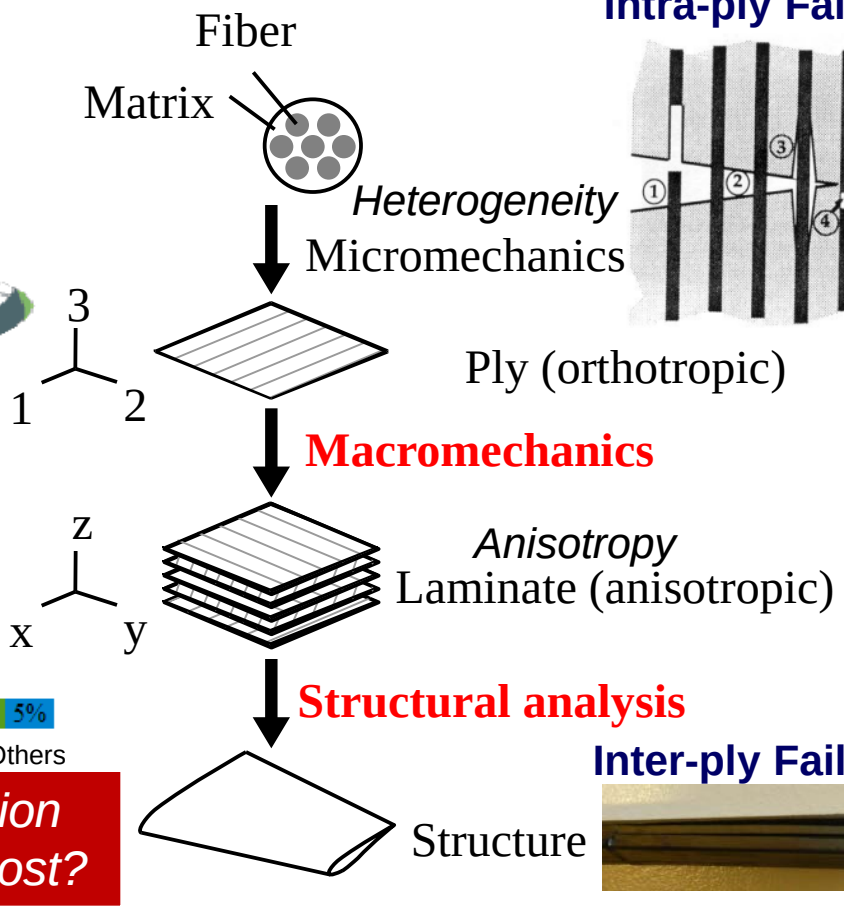
[e.g., Boeing - 787]

Materials used by weight

How to calculate stress and strain distribution with high accuracy and low computational cost?

How to predict damage/failure modes and loads with high precision and low computational cost?

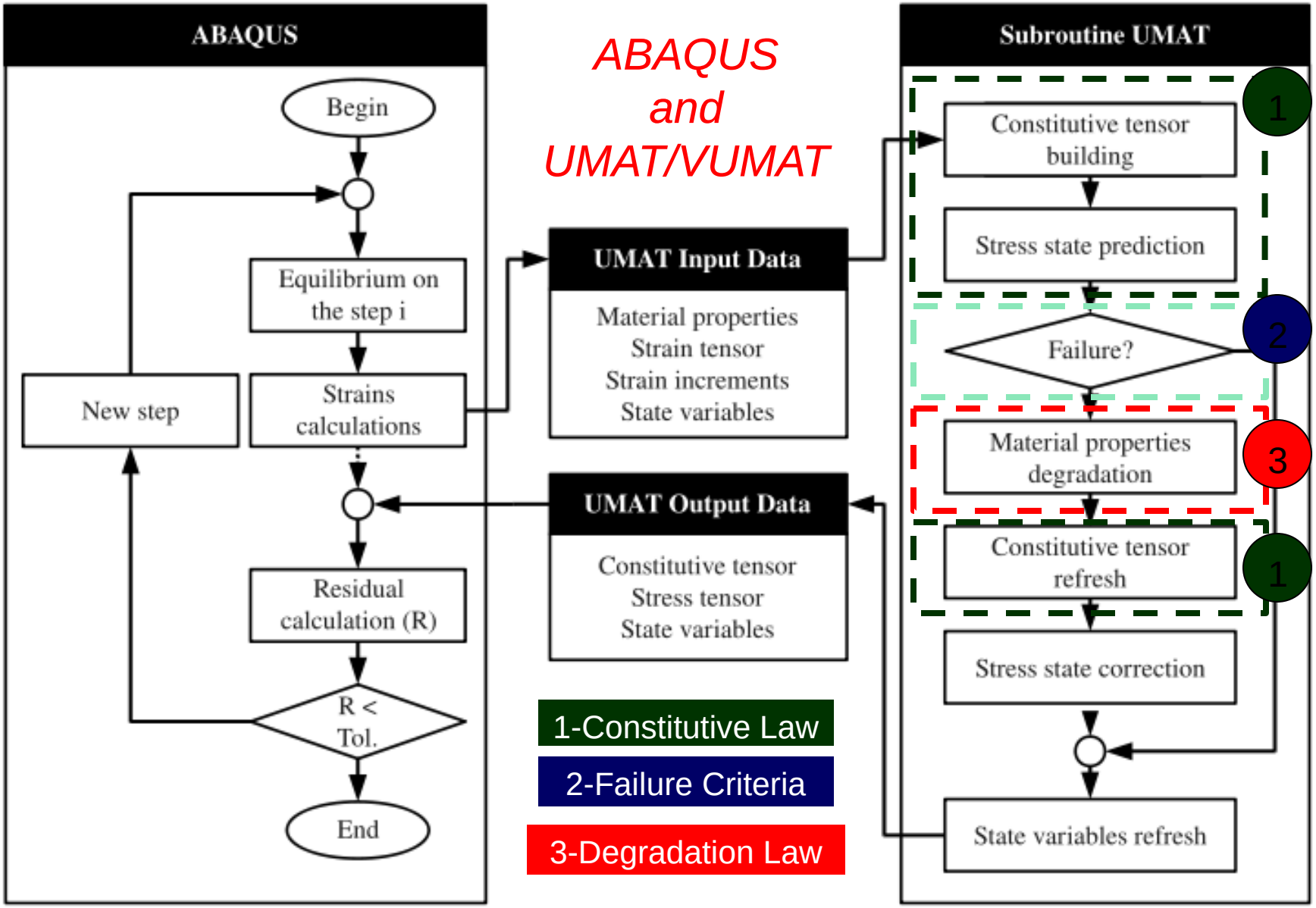
Challenges



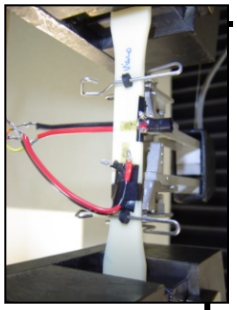
Intra-ply Failure

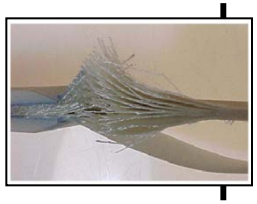
Inter-ply Failure

Damage Model Implementation
Filament Wound Structures



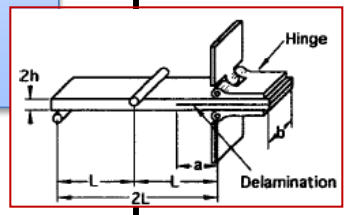
Damage Model Validation
Filament Wound Structures





Experimental tests

- Tensile
- Compression
- Shear
- Bending
- Mode I
- Mode II
- Mix Mode
- Hopkinson's bar



- 4 point Bending
- Indentation on plane and curved specimens
- Impact on plane and curved specimens

Model parameters

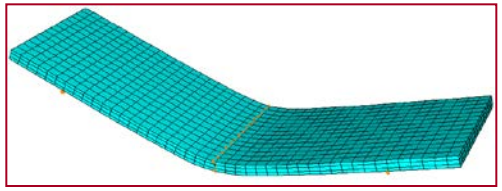
Model evaluation

Computational model

Abaqus

Abaqus implicit subroutines for plane and curved geometry
- UEL
- UMAT

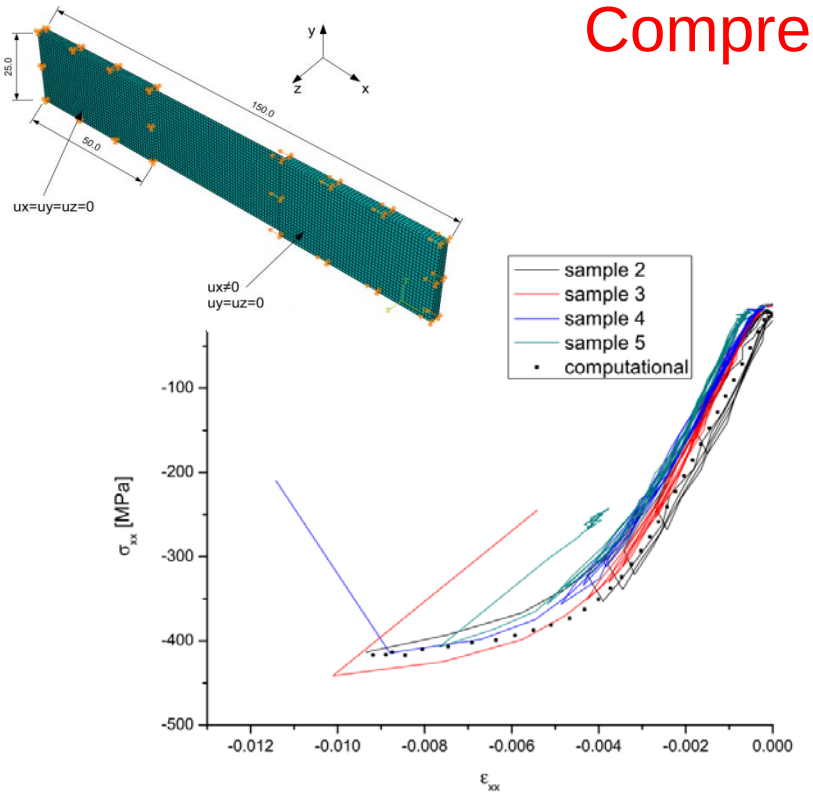
Abaqus explicit subroutines for plane and curved geometry
- VUEL
- VUMAT



Example of Validation Test Results
Filament Wound Structures

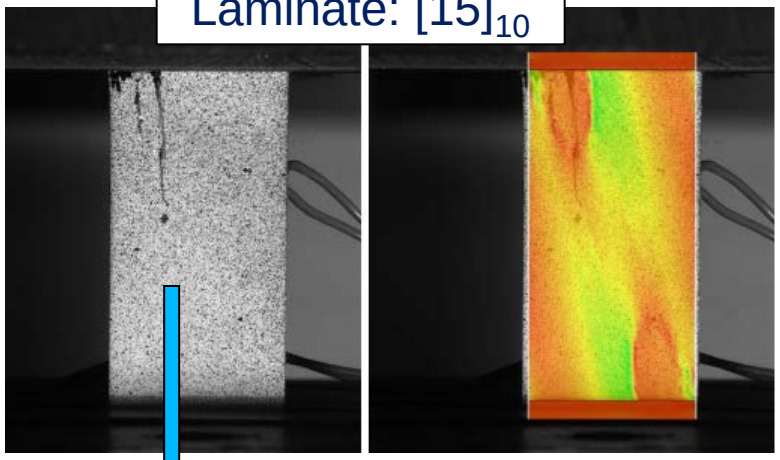
Compression Analyses

Uniaxial Compression Tests



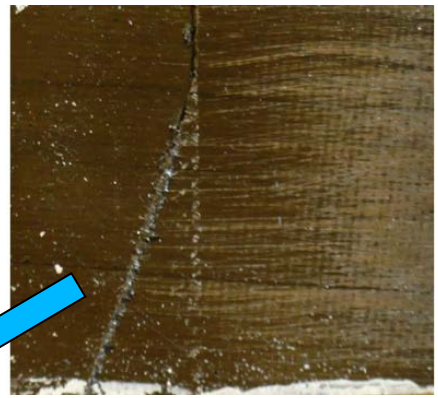
Maximum Failure Stress
~ 450 MPa

Laminate: $[15]_{10}$



Matrix Failure

Non-linear behavior



Micro-buckling and kinking of fibers

Local phenomena

Aerodynamics
Stability of Coaxial Free Jet Flow

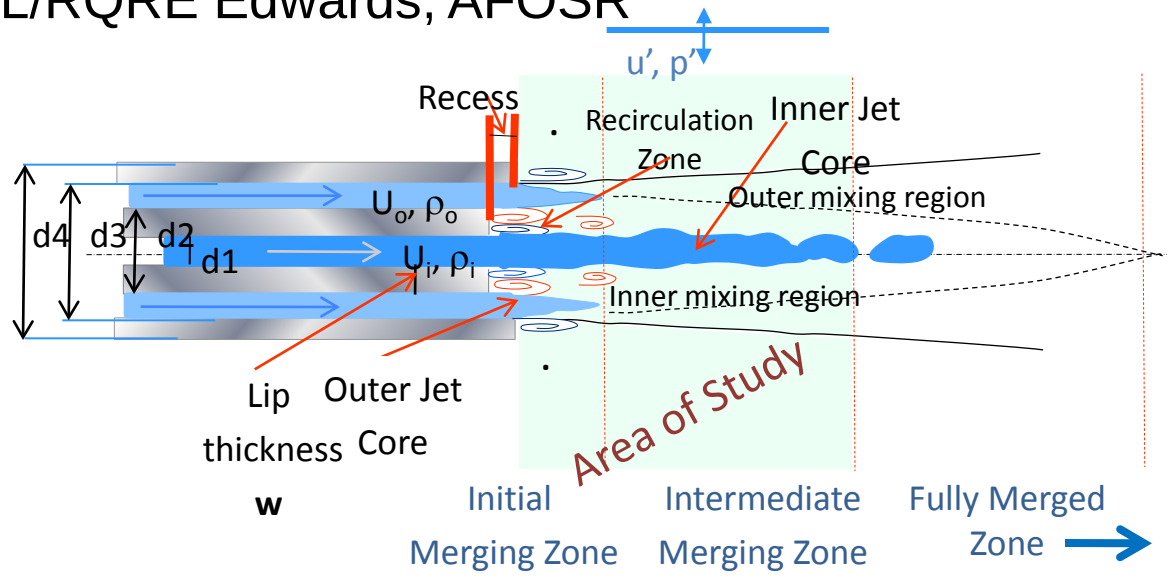
Collaborators: Fluminense Federal University, Brazil
AFRL/RQRE Edwards, AFOSR

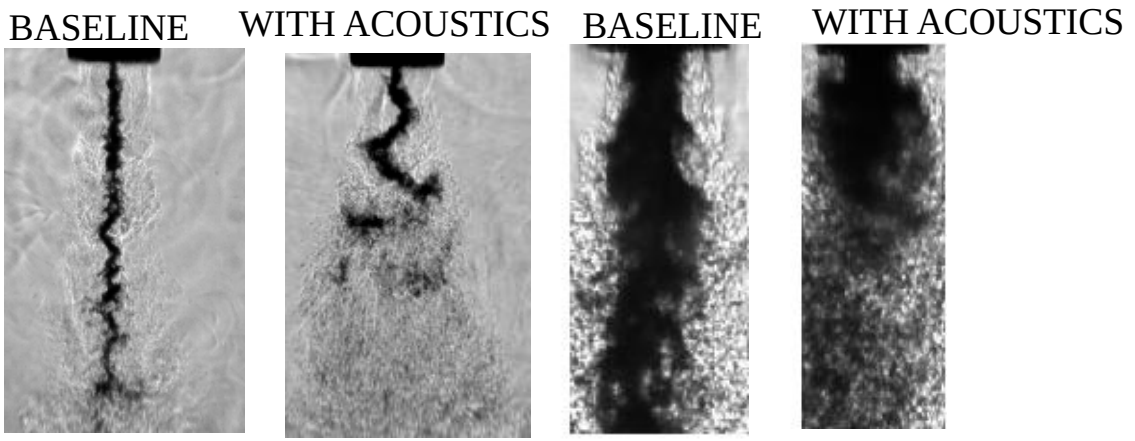
Objective: Perform a stability analysis for coaxial jets to better understand the natural hydrodynamic instabilities of this canonical geometry for liquid rocket engines

- Baseflow will be established
- The outer jet and the inner jet wall thickness will be incorporated into analysis

Benefits:

- Better understanding of the natural instability modes of this class of injectors and how the wall thickness affects the hydrodynamics





Examples of coaxial base and acoustic driven flows

Concluding Remarks
State of Latin American Research

- **Latin American research is growing fast and becoming more visible on the global scale.**
  - **Between 2000 and 2010***
    - Growth of more than 9% per year in scholarly output
    - 70% increase in its share of world papers and citations
- **SOARD Project Officers will continue to cover a broad range of topics in BAA seeking the best scientists of Latin America.**
  - Space portfolio will remain a key area to take advantage of unique recourses space research worldwide)
  - Group formed in AFOSR to coordinate space research worldwide.

* Research Trends Issue 31 November 2012